

Project 2

*OpenFlow Protocol Observation &
Flow Rule Installation*

Deadline: 2020/10/07 (WED) 23:55



Outline

☐ OpenFlow Messages

- Monitor traffic between ONOS & Switches
- OpenFlow Message Observation

☐ Install/ Delete Flow Rules

- Curl
- ONOS and Topology Setup
- Method 1: via Command “curl”
- Method 2: via ONOS Web GUI

☐ Project 2 Requirements

- Part 1: Answer Questions
- Part 2: Install Flow Rules
- Part 3: Create Broadcast Storm
- Bonus



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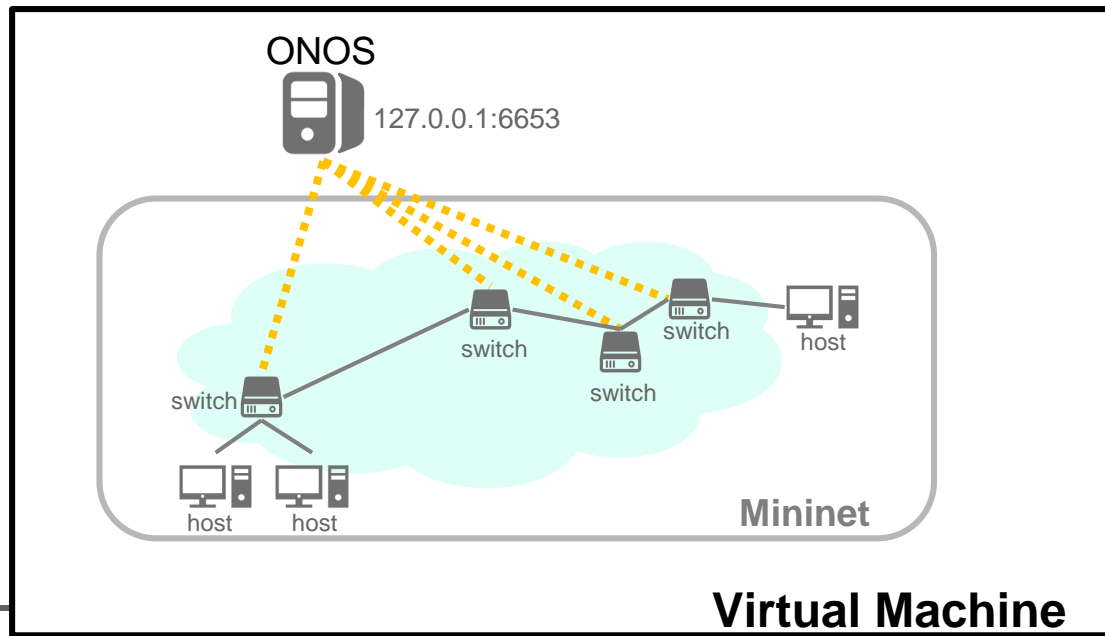
☐ Project 2 Requirements

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Openflow Protocol

- ❑ ONOS SDN controller uses Openflow messages to communicate with OVS switches.
- Packet-in/out message, Flow install/remove message, hello, etc.





Wireshark Installation

- ❑ Wireshark is an open-source and widely-used network packet analyzer
 - Can capture packets on any specified interface

- ❑ Installation steps:

1. Download package information

```
$ sudo apt update # update all packages information
```

2. Install Wireshark

```
$ sudo apt install wireshark
```

- ❑ Start Wireshark

```
$ sudo wireshark
```

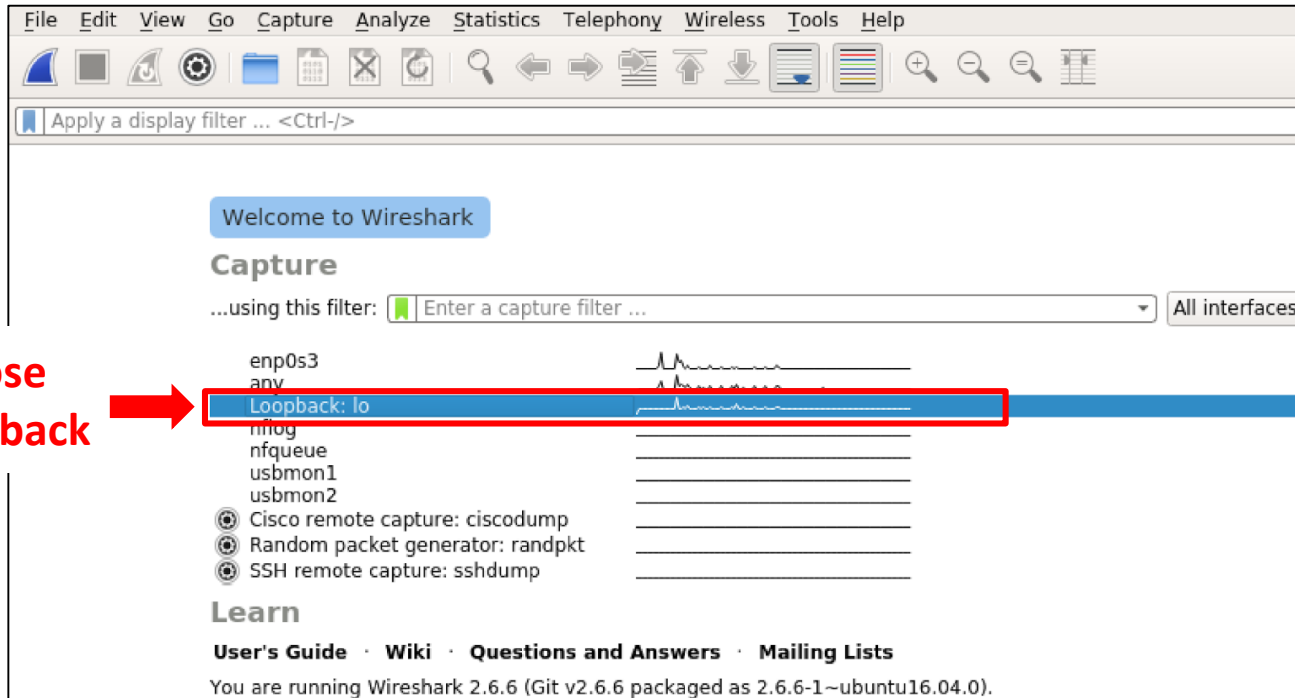




Capture Packets in Wireshark

- ❑ Both ONOS and Mininet runs on localhost of VM
- ❑ Capture packets on the Loopback (lo) interface

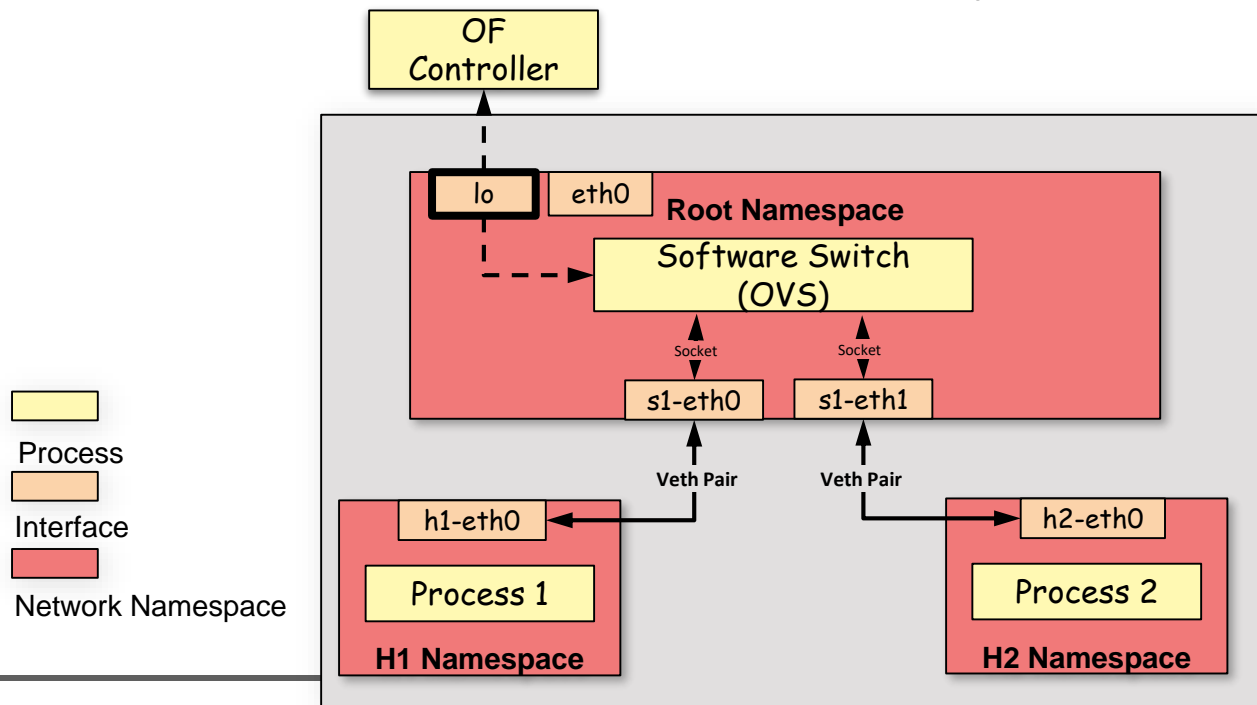
Choose
Loopback





Mininet and Network Namespace

- Mininet utilizes **network namespace** to emulate networks
 - OVS runs in the root network namespace
 - Each host runs in its own network namespace





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Capturing OpenFlow Messages

1. Start ONOS
2. Activate ReactiveForwarding

```
onos> apps -a -s # (optional) check activated application  
onos> app activate fwd # activate ReactiveForwarding
```

3. Start Mininet with default topology

```
$ sudo mn --controller=remote,127.0.0.1:6653
```

4. Ping a host in Mininet

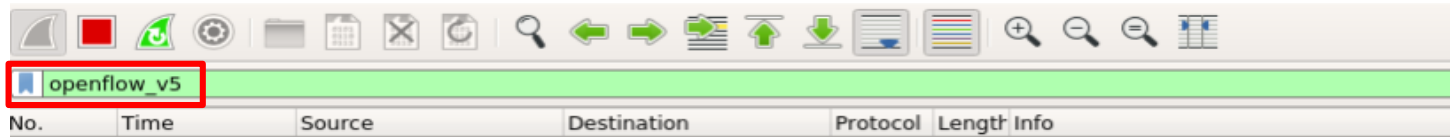
```
mininet> h1 ping h2 -c 5 # send five ICMP echo_request packets
```

5. Exit Mininet and stop capturing packets in Wireshark when ping terminates
6. Observe captured Openflow packets

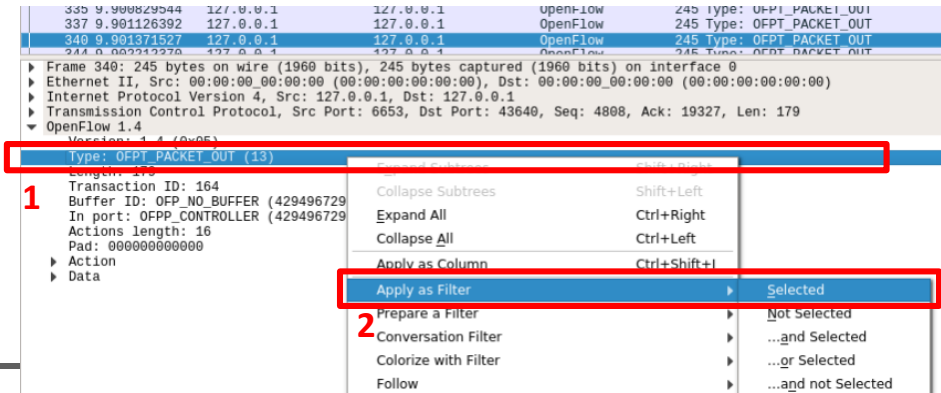


Filter in Wireshark

- ❑ Use keyword “openflow_v5” to filter **OpenFlow v1.4.0** packets
 - ONOS v2.2.0 uses Openflow v1.4.0



- Alternatively, apply filter in the following steps:
 1. Right click on the packet header field which you want to apply as filter
 2. Choose “Apply as Filter” and click “Selected”
 3. Wireshark will immediately filter out all the relevant packets

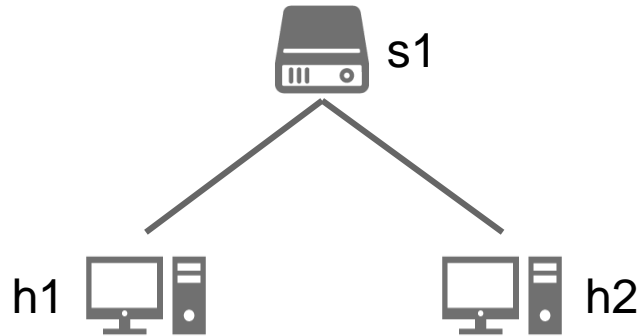




Minimal Topology in Mininet

- Default topology with a switch and two hosts connected

```
$ sudo mn --controller=remote,127.0.0.1:6653
```



- Manpage for command “mn”
 - <http://manpages.ubuntu.com/manpages/bionic/man1/mn.1.html>



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Curl—Command Tool For Transferring Data

☐ Command format

```
curl [options] [URL...]
```

☐ Transferring data with URL

```
$ curl -u <user:password> -X <command> -H <header> -d <data> [URL...]  
    # option "-X" specifies a HTTP request method  
    # option "-H" includes extra header in the HTTP request  
    # option "-d" sends specified data in a POST request  
    # URL (Uniform Resource Locator)
```

- "<data>" can be a file name prefixed with `@`

```
$ curl -u <user:password> -X <command> -H <header> -d @<file> [URL...]
```

☐ Manpage for command "curl"

- <http://manpages.ubuntu.com/manpages/xenial/man1/curl.1.html>



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ONOS & Topology Setup

1. Restart ONOS
 - a) <ctrl+c> in the ONOS log panel to shutdown the ONOS instance
 - b) Start ONOS

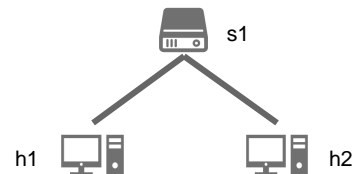
```
demo@SDN-NFV:~/onos$ ok clean
# ok is an alias of command "bazel run onos-local -- "
```

2. Deactivate Reactiveforwarding APP

```
onos> app deactivate fwd # deactivate ReactiveForwarding
```

3. Start Mininet with default (minimal) topology

```
$ sudo mn --controller=remote,127.0.0.1:6653
```



4. Make sure that two hosts **CAN NOT** ping each other

```
mininet> h1 ping h2
```

```
mininet> h1 ping h2
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
From 10.0.0.1 icmp_seq=1 Destination Host Unreachable
From 10.0.0.1 icmp_seq=2 Destination Host Unreachable
From 10.0.0.1 icmp_seq=3 Destination Host Unreachable
From 10.0.0.1 icmp_seq=4 Destination Host Unreachable
```



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 - REST & curl
 - ONOS and Topology Setup
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Create a JSON file of flow rules

- Example: json file for a flow rule

flows1.json

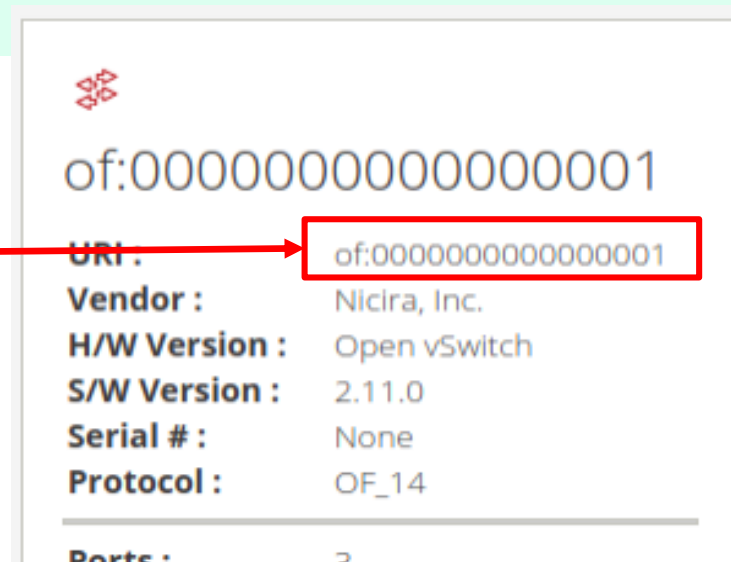
```
{
  "priority": 50000,
  "timeout": 0,
  "isPermanent": true,
  "deviceId":
  "of:0000000000000001",
  "treatment": {
    "instructions": [
      {
        "type": "OUTPUT",
        "port": "2"
      }
    ]
  },
  "selector": {
    "criteria": [
      {
        "type": "IN_PORT",
        "port": "1"
      }
    ]
  }
}
```



JSON File: Device ID

```
{
  "priority": 50000,
  "timeout": 0,
  "isPermanent": true,
  "deviceId": "of:000000000000000001",
  "treatment": {
    "instructions": [
      {
        "type": "OUTPUT",
        "port": "2"
      }
    ]
  },
  "selector": {
    "criteria": [
      {
        "type": "IN_PORT",
        "port": "1"
      }
    ]
  }
}
```

flows1.json



- DeviceID **MUST be** the URI, shown in the ONOS web GUI
- DeviceID is set by either ONOS or user specified topology file (i.e. *.py)



JSON File: Match Field of Flow Rule

```
{  
  "priority": 50000,  
  "timeout": 0,  
  "isPermanent": true,  
  "deviceId": "of:00000000000000001",  
  "treatment": {  
    "instructions": [  
      {  
        "type": "OUTPUT",  
        "port": "2"  
      }  
    ],  
    "selector": {  
      "criteria": [  
        {  
          "type": "IN_PORT",  
          "port": "1"  
        }  
      ]  
    }  
  }  
}
```

flows1.json

```
"selector": {  
  "criteria": [  
    {  
      "type": "IN_PORT",  
      "port": "1"  
    },  
    {...},  
    ...  
  ]  
}
```



JSON File: Action List of Flow Rule

```
{
  "priority": 50000,
  "timeout": 0,
  "isPermanent": true,
  "deviceId": "of:000000000000000001",
  "treatment": {
    "instructions": [
      {
        "type": "OUTPUT",
        "port": "2"
      }
    ]
  },
  "selector": {
    "criteria": [
      {
        "type": "IN_PORT",
        "port": "1"
      }
    ]
  }
}
```

flows1.json

```
"treatment": {
  "instructions": [
    {
      "type": "OUTPUT",
      "port": "2"
    },
    {...},
    ...
  ]
}
```



Upload JSON File to ONOS



- ❑ Install flow rules on ONOS with JSON file (**flows1.json**)

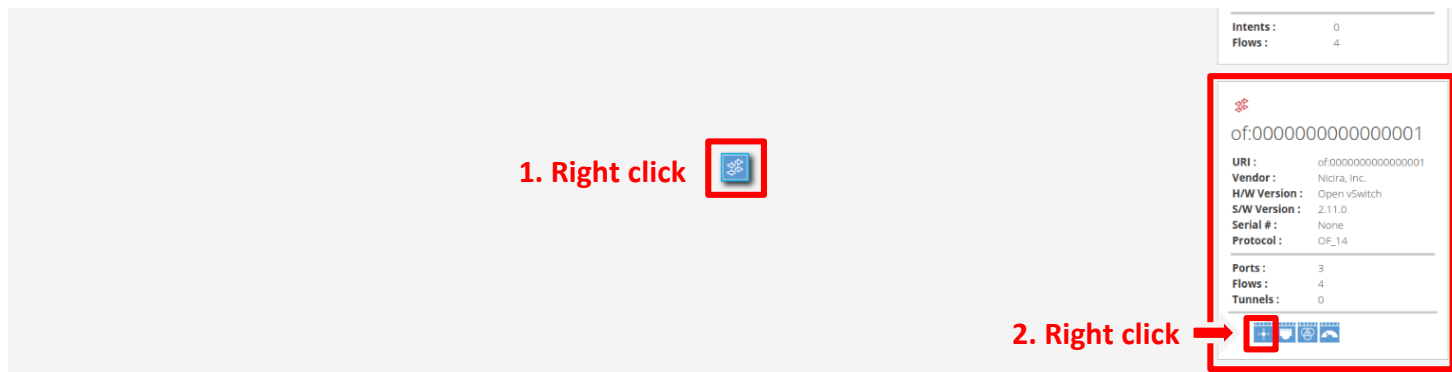
```
$ curl -u onos:rocks \  
> -X POST \  
> -H 'Content-Type: application/json' \  
> -d @flows1.json \  
> 'http://localhost:8181/onos/v1/flows/of:0000000000000001'
```

Device ID



Check whether the flow rule is installed

1. Go to ONOS web GUI
2. Left click on . Then, the panel of switch info will pop out
3. Left click on 



STATE	PACKETS	DURATION	FLOW PRIORITY	TABLE NAME	SELECTOR	TREATMENT	APP NAME
Added	0	36	50000	0	IN_PORT:1	imm[OUTPUT:2], cleared:false	*rest
Added	0	960	40000	0	ETH_TYPE:bddp	imm[OUTPUT:CONTROLLER], cleared:true	*core
Added	0	960	40000	0	ETH_TYPE:lldp	imm[OUTPUT:CONTROLLER], cleared:true	*core
Added	12	960	40000	0	ETH_TYPE:arp	imm[OUTPUT:CONTROLLER], cleared:true	*core



Check whether the flow rule is installed (Cont.)

SELECTOR			TREATMENT		APP NAME			
IN_PORT:1			imm[OUTPUT:2], cleared:false		*rest			
STATE	PACKETS	DURATION	FLOW PRIORITY	TABLE NAME	SELECTOR	TREATMENT	APP NAME	
Added	0	36	50000	0	IN_PORT:1	imm[OUTPUT:2], cleared:false	*rest	
Added	0	960	40000	0	ETH_TYPE:bddp	imm[OUTPUT:CONTROLLER], cleared:true	*core	
Added	0	960	40000	0	ETH_TYPE:ldp	imm[OUTPUT:CONTROLLER], cleared:true	*core	
Added	12	960	40000	0	ETH_TYPE:arp	imm[OUTPUT:CONTROLLER], cleared:true	*core	

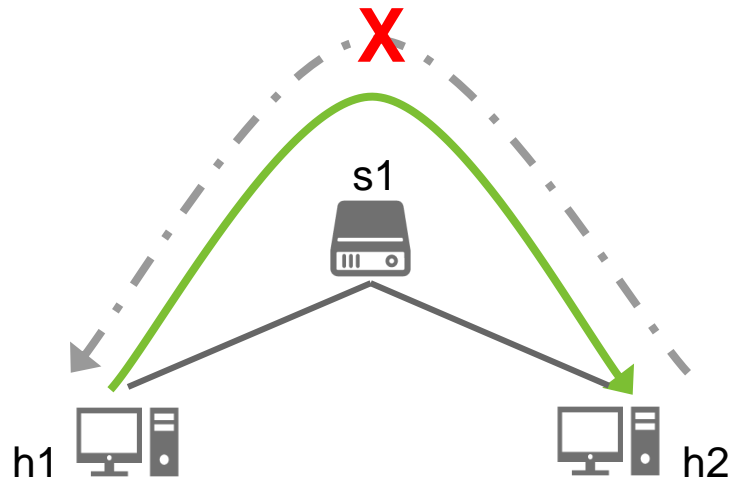
■ Flow Rule states:

- **PENDING_ADD**—this indicates that ONOS has received a request from the application to install the flow rule, but that flow has NOT yet been observed on the device.
- **ADDED**—once the flow rule subsystem observes the flow on the device it will transition to this state.



Why Hosts Still Can't Ping Each Other?

- Because we have **only** installed a flow rule for one direction
 - S1 can forward packets from h1 to h2
 - But, s1 CANNOT forward packets from h2 to h1
 - By default, S1 will drop a packet if the packet does not match any flow rule (i.e. table-miss flow rule)

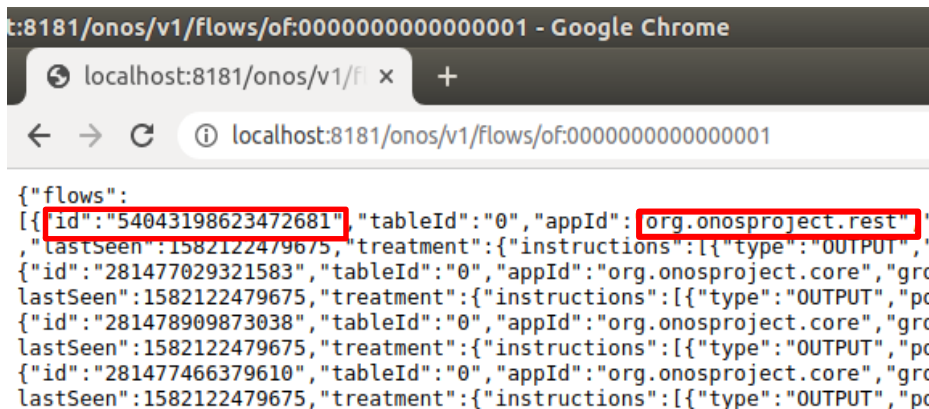




Delete Flow Rules

- Use URL to find the **flowID** of particular flow rules

Ex. <http://localhost:8181/onos/v1/flows/of:000000000000000001>



```
t:8181/onos/v1/flows/of:000000000000000001 - Google Chrome
localhost:8181/onos/v1/fi x +
localhost:8181/onos/v1/flows/of:000000000000000001

{"flows":
[{"id": "54043198623472681", "tableId": "0", "appId": "org.onosproject.rest",
, "lastSeen": 1582122479675, "treatment": {"instructions": [{"type": "OUTPUT",
{"id": "281477029321583", "tableId": "0", "appId": "org.onosproject.core", "gro
lastSeen": 1582122479675, "treatment": {"instructions": [{"type": "OUTPUT", "po
{"id": "281478909873038", "tableId": "0", "appId": "org.onosproject.core", "gro
lastSeen": 1582122479675, "treatment": {"instructions": [{"type": "OUTPUT", "po
{"id": "281477466379610", "tableId": "0", "appId": "org.onosproject.core", "gro
lastSeen": 1582122479675, "treatment": {"instructions": [{"type": "OUTPUT", "po
```

- flowID of the flow we just added is **54043198623472681**

- Alternatively, we could use “curl” to get flow information

```
$ curl -u onos:rocks -X GET -H 'Accept: application/json' \  
> 'http://localhost:8181/onos/v1/flows/of:000000000000000001'
```



Delete Flow Rules (Cont.)

- Then, delete the flow rule with flowID 54043198623472681

```
$ curl -u onos:rocks \  
> -X DELETE \  
> -H 'Accept: application/json' \  
> 'http://localhost:8181/onos/v1/flows/of:000000000000000001 \  
> /54043198623472681'
```

Flow ID

Device ID



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REST API on ONOS Web GUI

□ Browse <http://127.0.0.1:8181/onos/v1/docs>

ONOS Core REST API

ONOS Core REST API

docs : REST API documentation	Show/Hide	List Operations	Expand Operations
applications : Manage inventory of applications	Show/Hide	List Operations	Expand Operations
cluster : Manage cluster of ONOS instances	Show/Hide	List Operations	Expand Operations
configuration : Manage component configurations	Show/Hide	List Operations	Expand Operations
keys : Query and Manage Device Keys	Show/Hide	List Operations	Expand Operations
devices : Manage inventory of infrastructure devices	Show/Hide	List Operations	Expand Operations
diagnostics : Provides stream of diagnostic information	Show/Hide	List Operations	Expand Operations
nextobjectives : Get Flow objective next list	Show/Hide	List Operations	Expand Operations
flowobjectives : Manage flow objectives	Show/Hide	List Operations	Expand Operations
flows : Query and program flow rules	Show/Hide	List Operations	Expand Operations
groups : Query and program group rules	Show/Hide	List Operations	Expand Operations
hosts : Manage inventory of end-station hosts	Show/Hide	List Operations	Expand Operations



Using Web GUI to Install Flow Rule

- Fill out required fields ("appId" could be arbitrary string)

Select
POST
/flows/{deviceId}

Type In
deviceId
appId
JSON file

flows : Query and program flow rules Show/Hide List Operations Expand Operations

GET	/flows/table/{tableId}	Gets all flow entries for a table
DELETE	/flows/application/{appId}	Removes flow rules by application ID
GET	/flows/application/{appId}	Gets flow rules generated by an application
DELETE	/flows	Removes a batch of flow rules
GET	/flows	Gets all flow entries
POST	/flows	Creates new flow rules
DELETE	/flows/{deviceId}/{flowId}	Removes flow rule
GET	/flows/{deviceId}/{flowId}	Gets flow rules
GET	/flows/pending	Gets all pending flow entries
GET	/flows/{deviceId}	Gets flow entries of a device
POST	/flows/{deviceId}	Creates new flow rule

Implementation Notes
Creates and installs a new flow rule for the specified device.
Flow rule criteria and instruction description: <https://wiki.onosproject.org/display/ONOS/Flow+Rules>

Parameters

Parameter	Value	Description	Parameter Type	Data Type
deviceId	of:0000000000000001	device identifier	path	string
appId	app	application identifier	query	string
stream	<pre>{ "priority": 40000, "timeout": 0, "isPermanent": true, "deviceId": "of:0000000000000001", "treatment": { </pre>	flow rule JSON	body	Model Example Value

Parameter content type: application/json

```
{
  "priority": 40000,
  "timeout": 0,
  "isPermanent": true,
  "deviceId": "of:0000000000000001",
  "treatment": {
    "instructions": [
      {
        "type": "OUTPUT",
```



Transfer Flow Rule on Web GUI

- ❑ Click “Try it out!”
 - Web will pass the JSON stream to ONOS
 - Code 201 represent HTTP Request granted
 - In case of “curl”, use “-i” option to include HTTP Response headers in the output

The screenshot shows the ONOS Web GUI interface. At the top, there are input fields for 'appId' (set to 'app'), 'application identifier', 'query', and 'string'. Below these, there are sections for 'stream' and 'flow rule JSON'. The 'stream' section shows a JSON object:

```
{ "type": "IN_PORT", "port": "1" }
```

. The 'flow rule JSON' section shows a JSON object:

```
{ "priority": 40000, "timeout": 0, "isPermanent": true, "deviceId": "of:0000000000000001", "treatment": { "instructions": [ { "type": "OUTPUT", "port": "CONTROLLER" } ] } }
```

. Below these sections, there is a 'Response Messages' table with columns: HTTP Status Code, Reason, Response Model, and Headers. The table shows a status code of 200 with the reason 'successful operation'. Below the table, there is a 'Try it out!' button, which is highlighted with a red box. Below the button, there is a 'Curl' section with a pre-filled curl command:

```
curl -X POST --header 'Content-Type: application/json' --header 'Accept: application/json' -d '{ \ "priority": 40000, \ "timeout": 0, \ "isPermanent": true, \ "deviceId": "of:0000000000000001", \ "treatment": { \ "instructions": [ \ { \ "type": "OUTPUT", \ "port": "2" \ } \ ] \ }, \ "selector": { \ "criteria": { \ { \ "type": "IN_PORT", \ "port": "1" \ } \ } \ } \ } , \ "http://127.0.0.1:8181/onos/v1/flows/of%3A0000000000000001?appId=app' }
```

HTTP response replied by ONOS

The screenshot shows the details of the HTTP response. It is divided into three sections: 'Response Body', 'Response Code', and 'Response Headers'. The 'Response Body' section shows 'no content'. The 'Response Code' section shows '201 status code 201', where '201' is highlighted with a red box. The 'Response Headers' section shows a JSON object:

```
{ "content-length": "0", "location": "http://127.0.0.1:8181/onos/v1/flows/of:0000000000000001", "server": "Jetty(9.4.18.v20190429)", "content-type": null }
```



Delete Flow Rule via ONOS Web GUI

□ Same procedure as installing flow rules

flows : Query and program flow rules Show/Hide List Operations Expand Operations

GET	/flows/table/{tableId}	Gets all flow entries for a table
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GET	/flows	Gets all flow entries
POST	/flows	Creates new flow rules
DELETE	/flows/{deviceId}/{flowId}	Removes flow rule
GET	/flows/{deviceId}/{flowId}	Gets flow rules
GET	/flows/pending	Gets all pending flow entries
GET	/flows/{deviceId}	Gets flow entries of a device
POST	/flows/{deviceId}	Creates new flow rule

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Parameters

Parameter	Value	Description	Parameter Type	Data Type
deviceId	or:0000000000000001	device identifier	path	string
appId	app	application identifier	query	string
stream	<pre>{ "priority": 40000, "timeout": 0, "isPermanent": true, "deviceId": "of:0000000000000001", "treatment": {</pre>	flow rule JSON	body	Model Example Value

Parameter content type: application/json ▼

```
{
  "priority": 40000,
  "timeout": 0,
  "isPermanent": true,
  "deviceId": "of:0000000000000001",
  "treatment": {
    "instructions": [
      {
        "type": "OUTPUT",
```



Outline

- ☐ OpenFlow Messages
- ☐ Install/ Delete Flow Rules
- ☐ **Project 2 Requirements**
 - **Part 1: Answer Questions (30%)**
 - **Part 2: Install Flow Rules (40%)**
 - **Part 3: Create Broadcast Storm (30%)**
 - **Bonus (+10%)**



Part 1: Answer Questions

❑ Preparation:

1. Start capturing packets on the loopback interface with Wireshark.
2. Create a topology mentioned before (i.e. h1-s1-h2).
3. Activate “org.onosproject.fwd”.
4. Execute command “h1 ping h2 -c 5” in Mininet CLI.
5. Exit Mininet and stop capturing packets, when ping terminates.

❑ Questions:

1. How many OpenFlow **headers** of type “OFPT_FLOW_MOD” are there among all the packets?

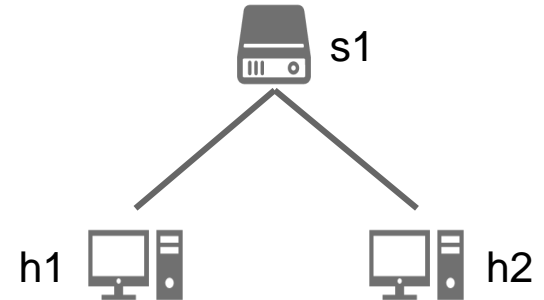
Hint: A single packet may contain more than one Openflow headers.

2. What are the **matching fields** and the corresponding **actions** in each of “OFPT_FLOW_MOD” messages?
3. What are the values of the **priority** fields of all “OFPT_FLOW_MOD” messages?



Part 2: Install Flow Rules (1/3)

- ❑ Please deactivate all the apps, **except those** initially activated.
“org.onosproject.hostprovider”,
“org.onosproject.lldpprovider”,
“org.onosproject.optical-model”,
“org.onosproject.openflow-base”,
“org.onosproject.openflow”,
“org.onosproject.drivers”
and “org.onosproject.gui2”.
- ❑ Use the following topology (i.e. h1-s1-h2):
- ❑ Hand in all your flow rule files (.json)



Note: Host1 should be able to ping host2 if you install the flow rules correctly.



Part 2: Install Flow Rules (2/3)

- ❑ Install following flow rules to forward ARP packets
 - Matching fields
 - Ethernet type (ARP)
 - Actions
 - Output from port, forwarding ARP packets to hosts
- ❑ Verify the flow rules your installed

```
mininet> h1 arping h2 # send ARP request
```

```
mininet> h1 arping h2
ARPING 10.0.0.2 from 10.0.0.1 h1-eth0
Unicast reply from 10.0.0.2 [42:75:EB:67:61:F6] 4.324ms
Unicast reply from 10.0.0.2 [42:75:EB:67:61:F6] 4.957ms
Unicast reply from 10.0.0.2 [42:75:EB:67:61:F6] 4.928ms
Unicast reply from 10.0.0.2 [42:75:EB:67:61:F6] 4.834ms
```

Hint: The priority of this flow rule MUST be higher than the flow rule initially installed (>40000), and less than 65535.



Part 2: Install Flow Rules (3/3)

- ❑ Install flow rules to forward IPv4 packets
 - Matching fields
 - IPv4 destination address
 - Actions
 - Output from port, forwarding IPv4 packets to hosts
- ❑ Verify the flow rules your installed

```
mininet> h1 ping h2 # send ICMP request
```

```
mininet> h1 ping h2
PING 10.0.0.2 (10.0.0.2) 56(84) bytes of data.
64 bytes from 10.0.0.2: icmp_seq=1 ttl=64 time=9.00 ms
64 bytes from 10.0.0.2: icmp_seq=2 ttl=64 time=2.54 ms
64 bytes from 10.0.0.2: icmp_seq=3 ttl=64 time=0.188 ms
64 bytes from 10.0.0.2: icmp_seq=4 ttl=64 time=0.075 ms
```

Hint:

1. Switch may remove flow rules installed previously after a period of time.
2. Match fields may have dependency; please refer to OpenFlow spec v1.4.0.



Part 3: Create Topology with Broadcast Storm

☐ Steps:

1. Create a topology that may cause a “**Broadcast Storm**”.
 2. Install flow rules on switches of the network.
 3. Send packets from a host to another host.
 4. Observe statuses of links of the network and the CPUs utilization of VM
-
- ☐ Do NOT activate any other APPs, except for those initially activated by ONO
 - ☐ Describe what you have observed and explain why the broadcast storm occurred.
 - ☐ Hand in both Topology file (*.py) and flow rule files (*.json)

Hint: ONOS would initially install several flow rules.



Naming Convention

□ Use the following convention to name the files created in both part 2 and part 3.

1. Python script for the topology: `topo_<studentID>.py`
2. JSON files for flow rules: `flows_s<i>-<j>_<studentID>.json`

- “i” is the switch number
- “j” is the flow rule number, starting from 1, on a switch.

e.g.

File Name	Meaning
flows_s1-1_0748787.json	#1 flow rule to install on s1
flows_s1-2_0748787.json	#2 flow rule to install on s1
flows_s2-1_0748787.json	#1 flow rule to install on s2



Bonus

- ❑ Activate only “org.onosproject.fwd” and other initially activated APPs.
- ❑ Use mininet default topology and let host1 ping host2.
- ❑ Please describe what happens in the data and control planes, starting from the time host1 starts pinging host2 until host2 receives the first ICMP request
 - Please also write down each operation made by the data plane and control plane
- ❑ Please refer to the ONOS ReactiveForwarding application
 - <https://github.com/opennetworkinglab/onos/blob/onos-2.2/apps/fwd/src/main/java/org/onosproject/fwd/ReactiveForwarding.java>



Report

About Submission



Report Submission (1/2)

Files:

- A **report**: **project2_<studentID>.pdf**
 1. Part 1: Answers to those three questions
 2. Part 2, Part 3 & Bonus:
Take screenshots of your procedure and also explain in detail
 3. What you've learned or solved
- Several **JSON files** created, with correct naming convention, in both part 2 and part 3
- A **Python script** for creating topology in part 3



Report Submission (2/2)

Submit:

- Create folder: **project2_<studentID>**
- In project2_<studentID>, create part2 and part3 directory and move files (i.e. *.json, *.py) into the corresponding directory

```
project2_0748787/  
├── part2  
│   ├── flows_s1-1_0748787.json  
│   ├── flows_s1-2_0748787.json  
│   └── flows_s1-3_0748787.json  
├── part3  
│   ├── flows_s1-1_0748787.json  
│   ├── flows_s1-2_0748787.json  
│   ├── flows_s2-1_0748787.json  
│   ├── flows_s3-1_0748787.json  
│   └── topo_0748787.py  
└── project2_0748787.pdf  
  
2 directories, 9 files
```

- Zip into a zip file: **project2_<studentID>.zip**
- Incorrect naming convention or format subjects to not scoring



Q & A

Thank you



References

❑ OpenFlow spec v1.4.0

- <https://www.opennetworking.org/wp-content/uploads/2014/10/openflow-spec-v1.4.0.pdf>

❑ ONOS REST API

- <https://wiki.onosproject.org/display/ONOS/Appendix+B%3A+REST+API>

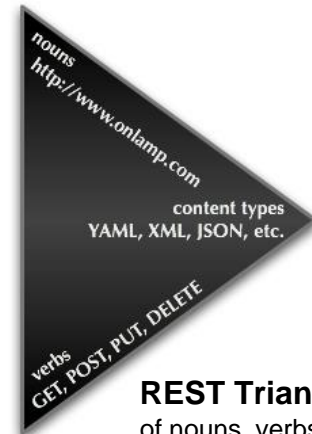
❑ JSON Format for Installing Flow Rules

- <https://wiki.onosproject.org/display/ONOS/Flow+Rules>



Appendix—REST (REpresentational State Transfer)

- ❑ REST is a **software architectural style** for creating Web services
- ❑ Architectural constraints:
 - Client-server architecture
 - Stateless
 - Cacheable
 - Uniform interface
 - Layered system
- ❑ Allow us to access and manipulate web resources
 - Commonly we use HTTP method
 - Payload could be formatted in HTML, XML, JSON



REST Triangle

of nouns, verbs and content types

Source: Soul & Shell Blog